Aram Chaos Exploration Zone

Workshop Abstract #1048

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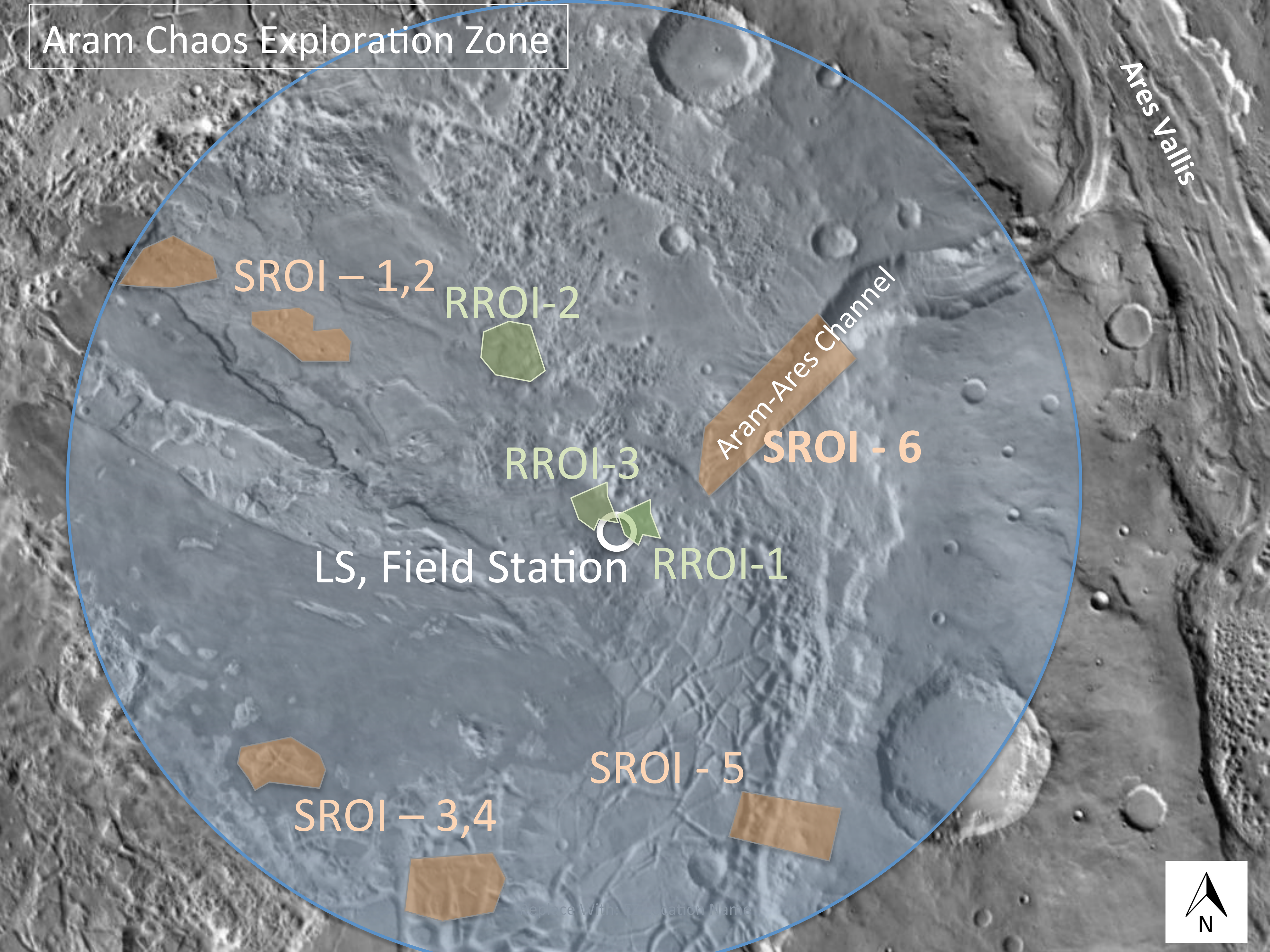
First Landing Site (LS)/Exploration Zone (EZ) Workshop for Human Missions to the Surface of Mars

Houston, TX

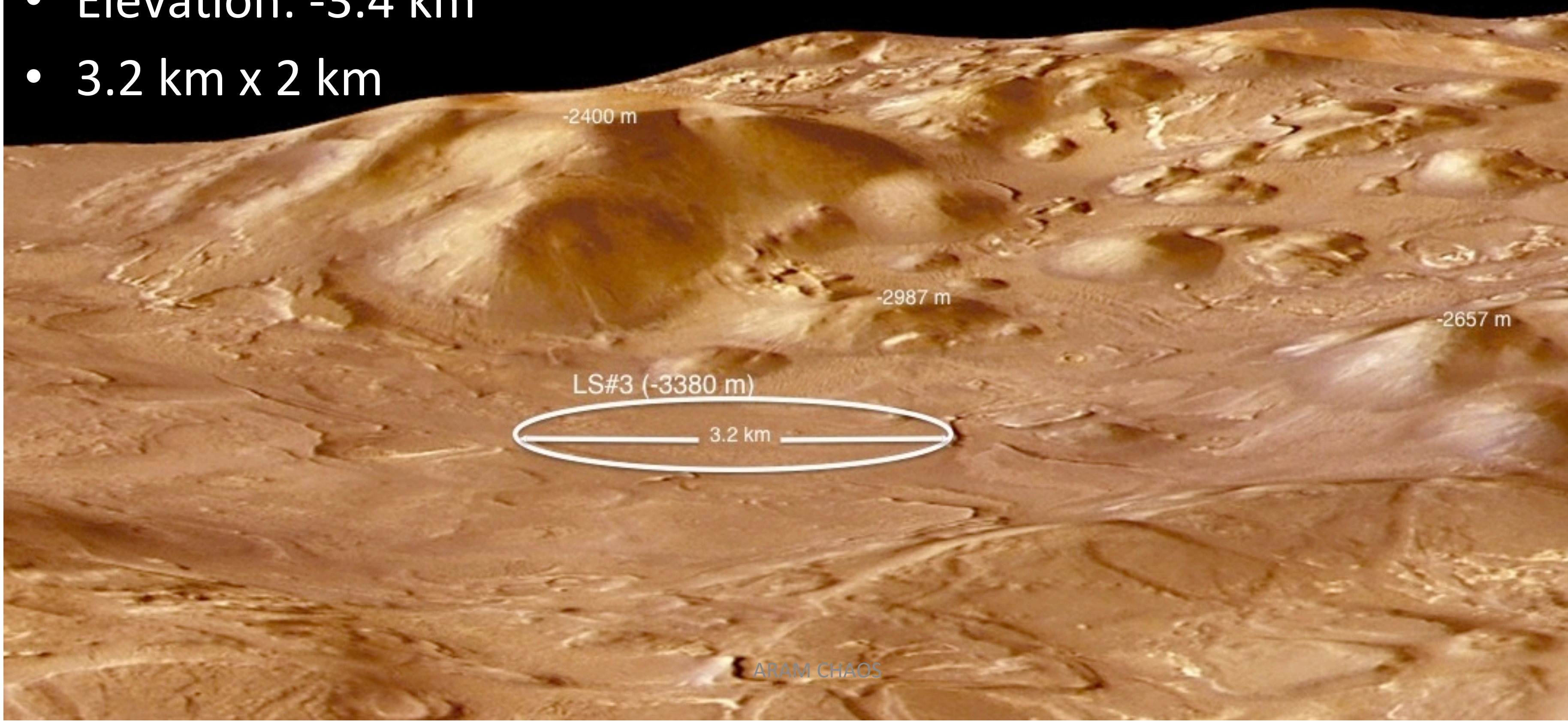
28 October 2015



Aram Chaos Exploration Zone
Ares Vallis
SROI – 1,2
RROI-2
Aram-Ares Channel
SROI - 6
RROI-3
LS, Field Station
RROI-1
SROI - 5
SROI – 3,4
N

Landing Zone – Surface Field Station

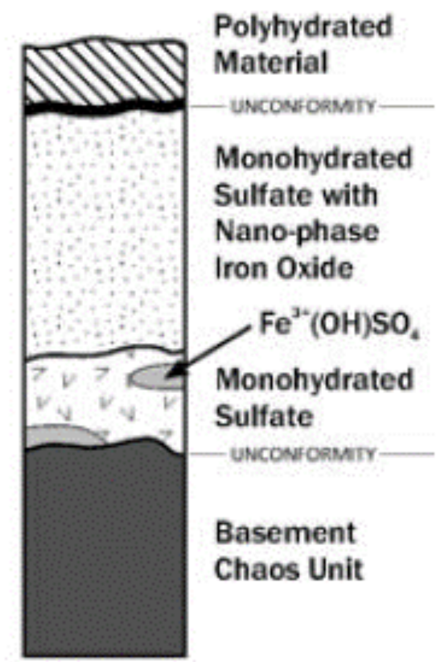
- Latitude: 2º 26’ 40” N
- Longitude: 19º 44’ 02” W
- Elevation: -3.4 km
- 3.2 km x 2 km



[in order of priority: addressing threshold first, then qualifying]

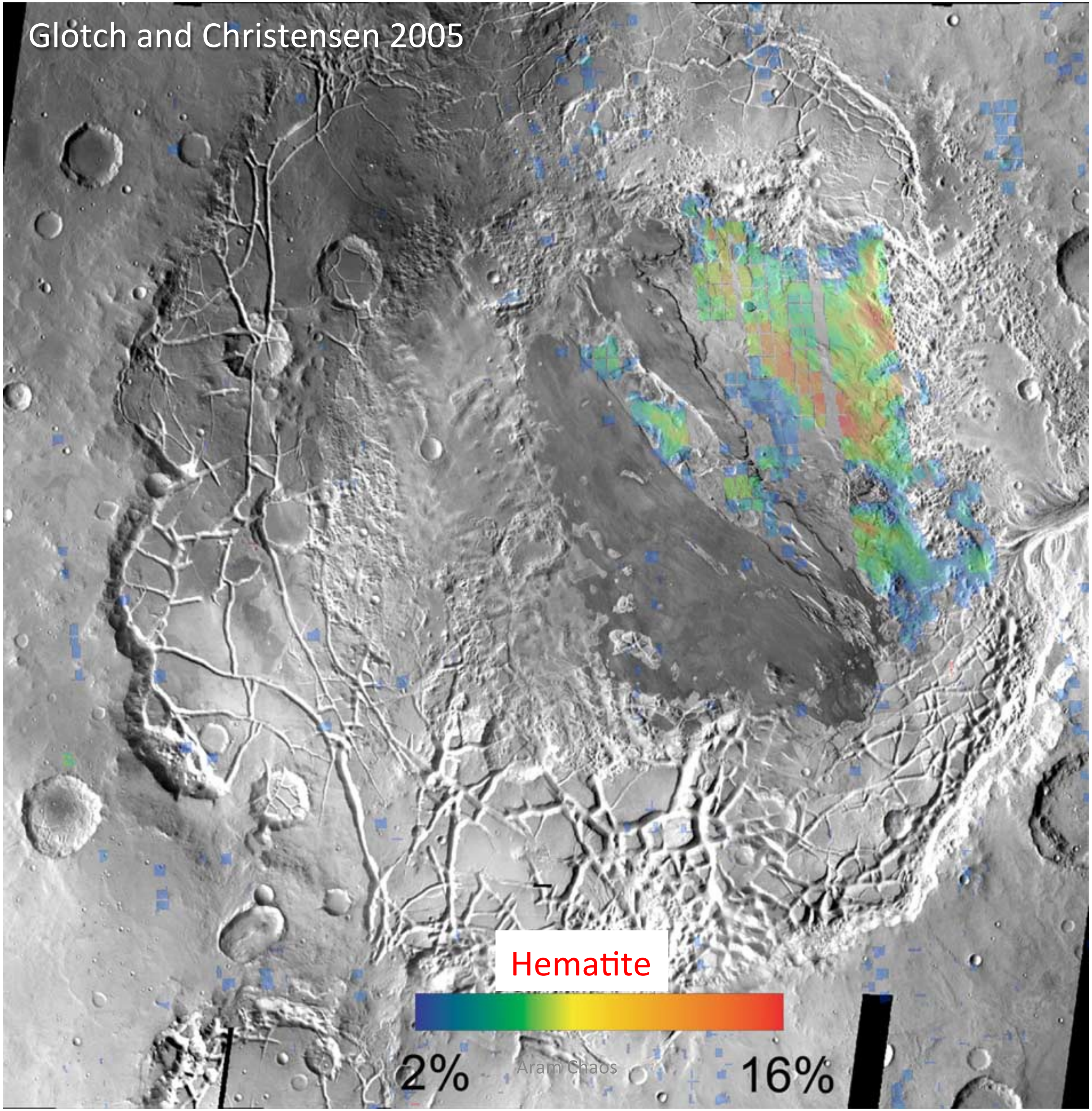
SCIENCE ROIs

Aram Chaos Science Overview

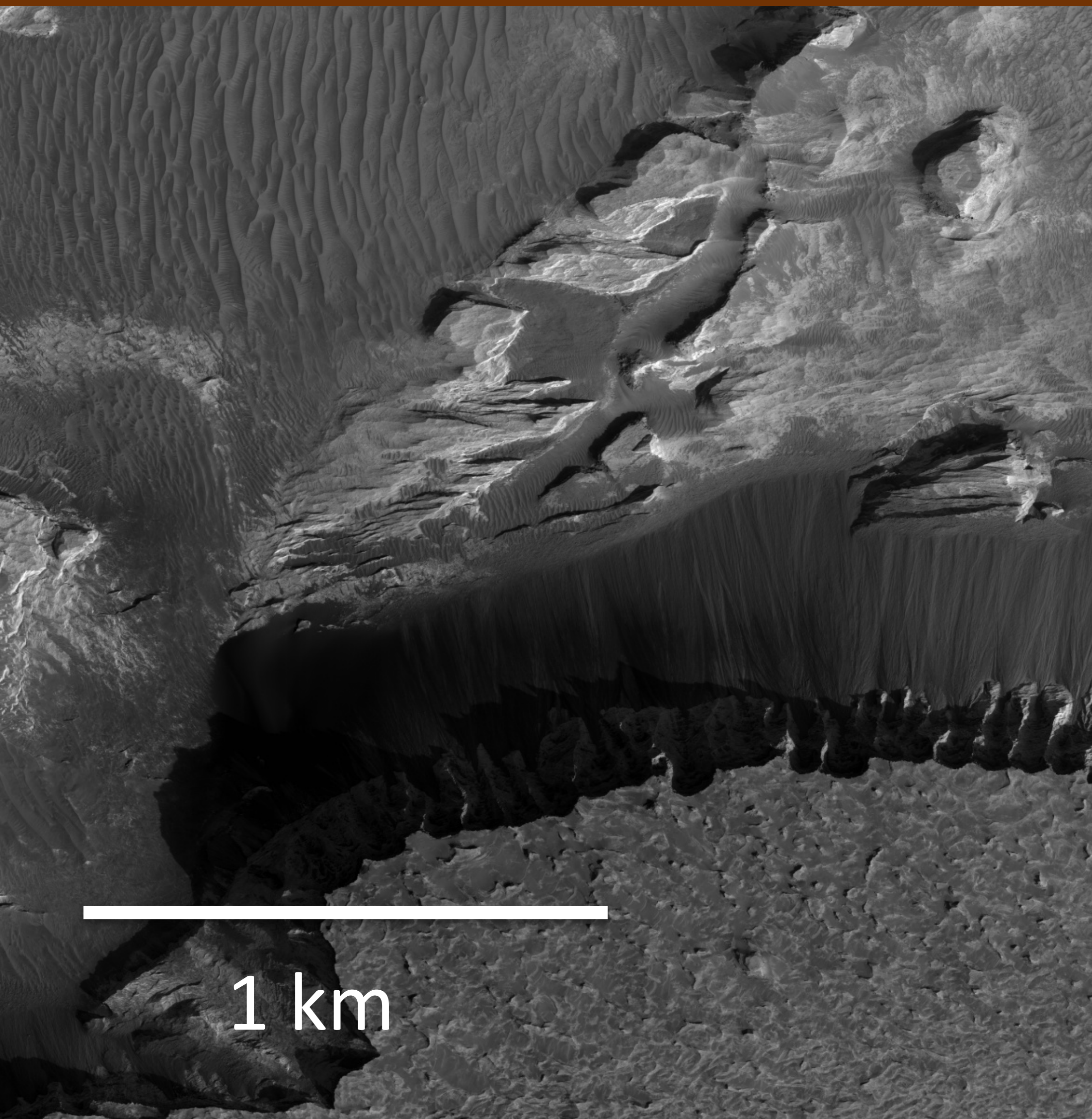


Lichtenberg et al. 2010

- Geologic History
  - Impact crater fill
  - Groundwater accumulation (~ Myr)
  - Discharge
  - Repeated cycles
- Past habitability in subsurface environment
- Hesperian atmosphere preservation – evaporite minerals
- Aqueous processes
- Significant chronological implications

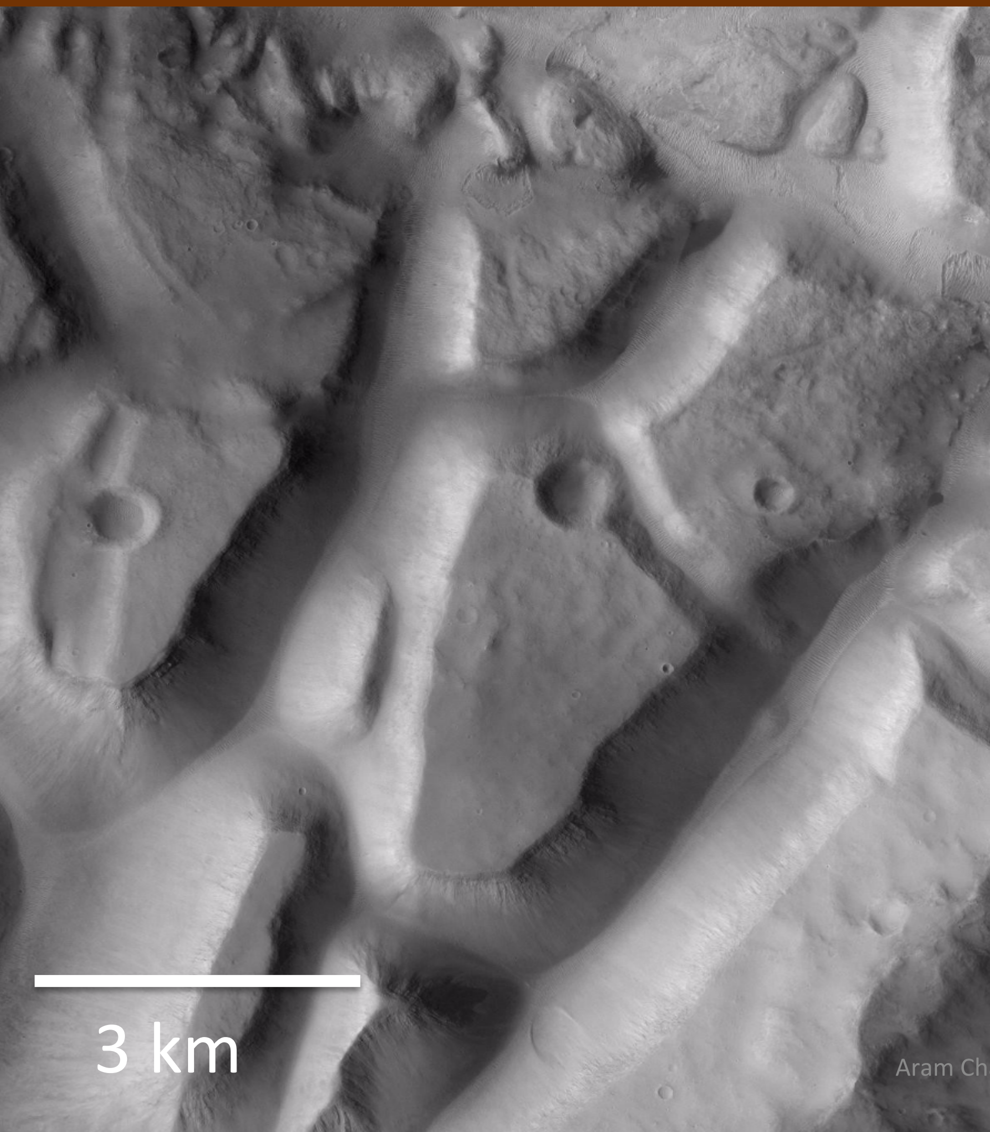

Glotch and Christensen 2005
Hematite
2%
16%
Aram Chaos

Science ROI 1,2: Evaporite Capping Units



- 3°47′ N, 20°55′ W; -2.7 km
- Later stage aqueous events
- Hematite/sulfate units linked to Meridiani Planum, Valles Marineris
- Potentially linked to global processes in Hesperian
  - Unanswered questions about timing
  - Chronology important

Science ROI 3,4: Subsurface Lake

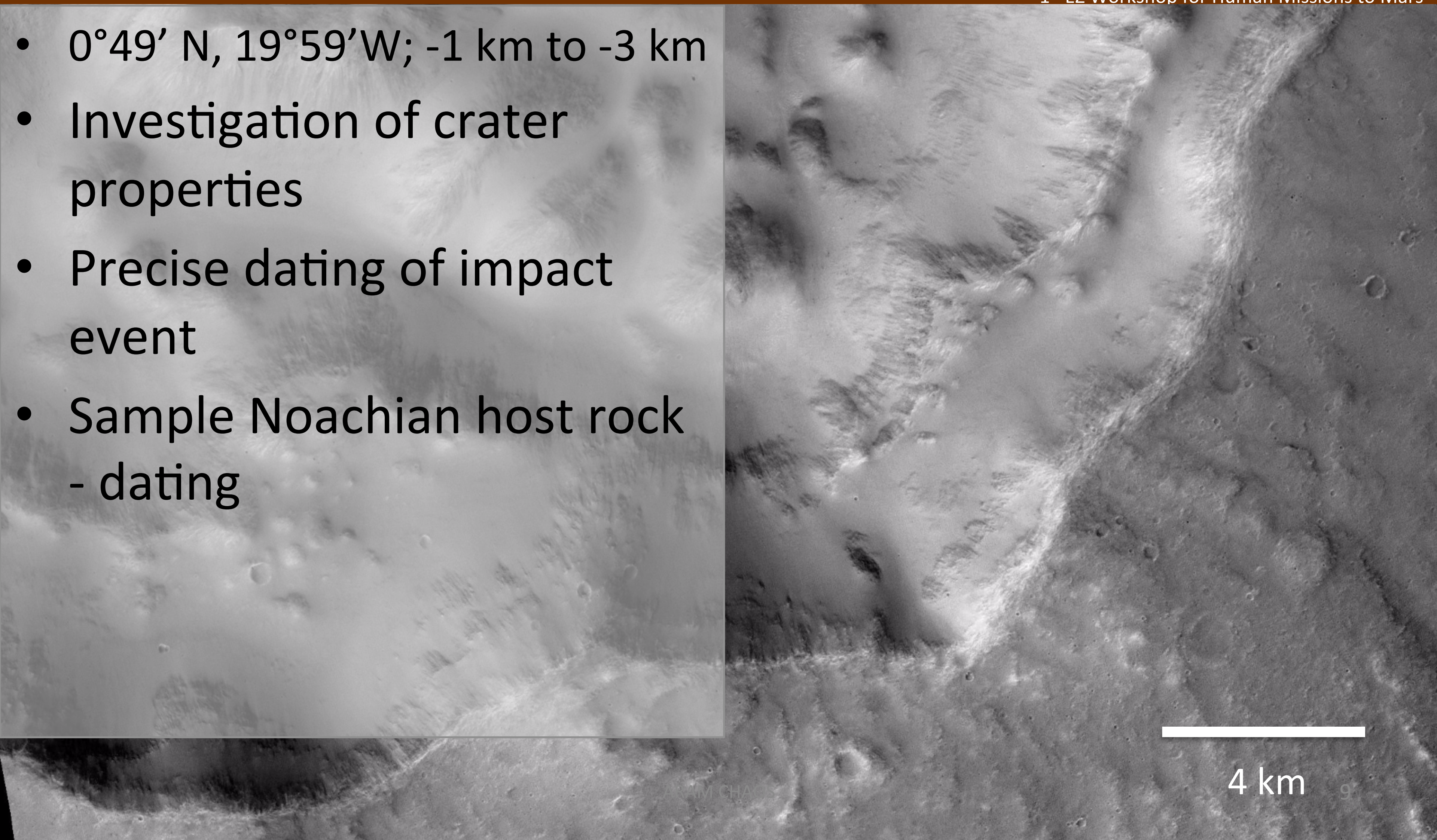


- 1°28’ N, 20°40’ W; -2.1 to -2.5 km
- Aram Chaos hosted a substantial subsurface lake for potentially several millions of years (Roda et al. 2014)

- Sediments hosting this lake are strong candidates for preserving evidence for past life.
  - Subsurface habitat is favorable – radiation protection
  - Long lived liquid water – large quantities
  - Capping materials protect from erosion
  - Basaltic aquifers typically have neutral-alkaline pH

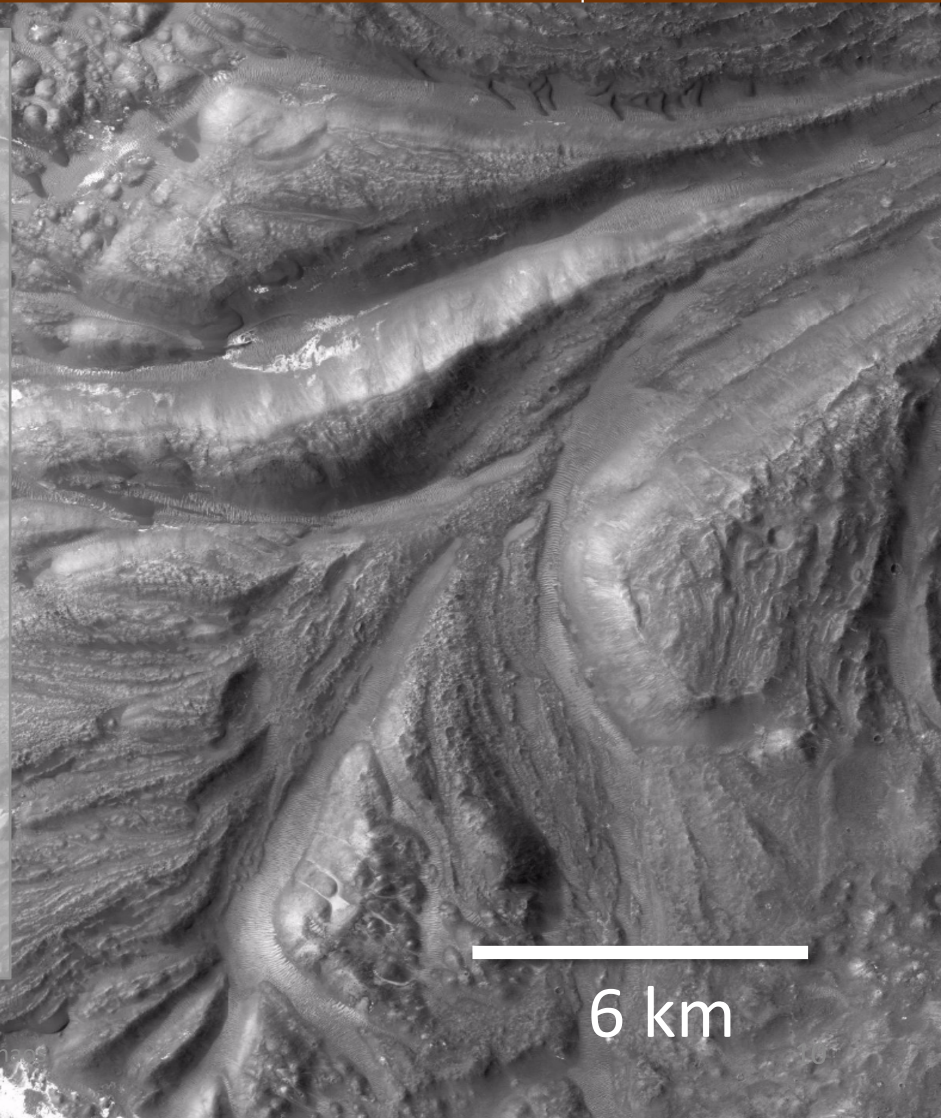
Science ROI-5 : Crater Rim

- 0°49’ N, 19°59’W; -1 km to -3 km
- Investigation of crater properties
- Precise dating of impact event
- Sample Noachian host rock - dating

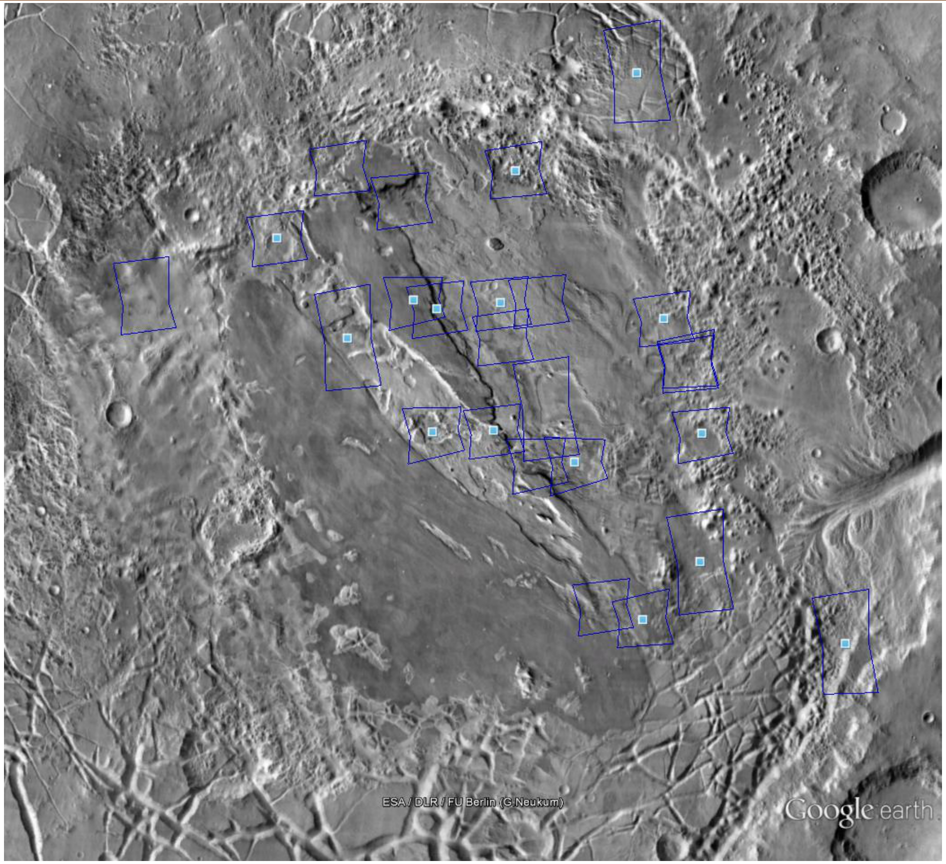


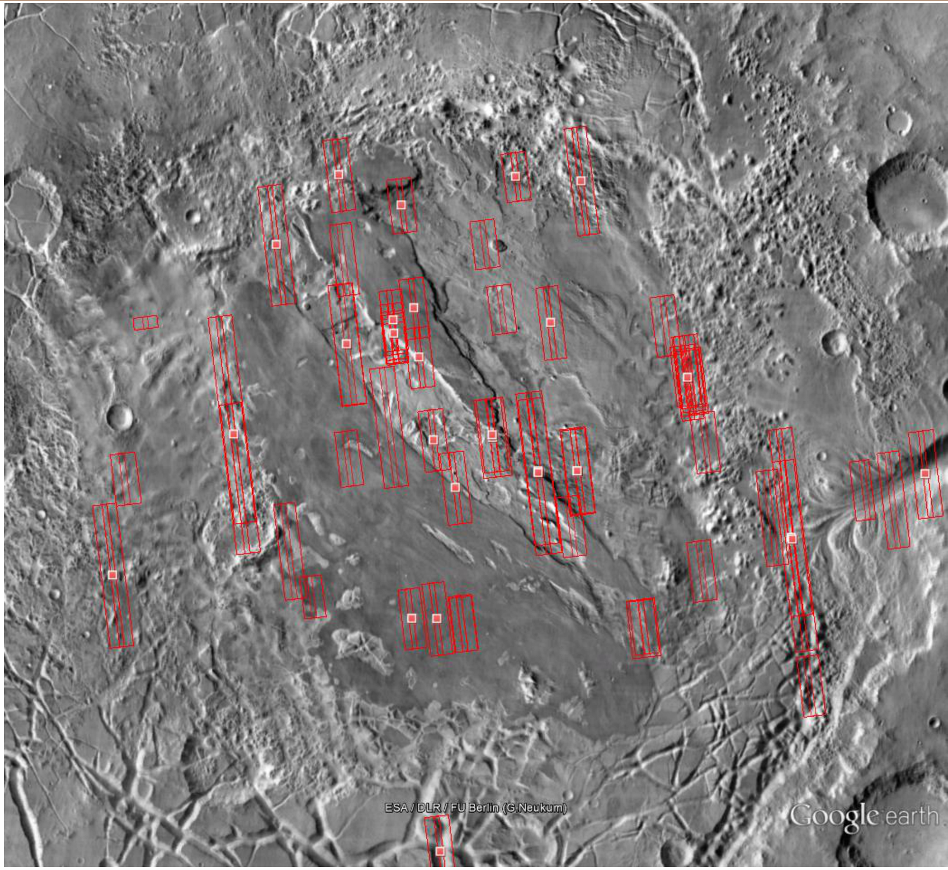
Science ROI-6 Aqueous Features

- 2°26' N, 19°25 W; -3 km
- Channel features preserve complex history
  - Multiple outflow events
- Linked to other similar events occurring globally
- Many open questions:
  - Frequency?
  - Recharge?
  - Water source/composition?
  - Host sediments?



Data Coverage CRISM, HiRISE



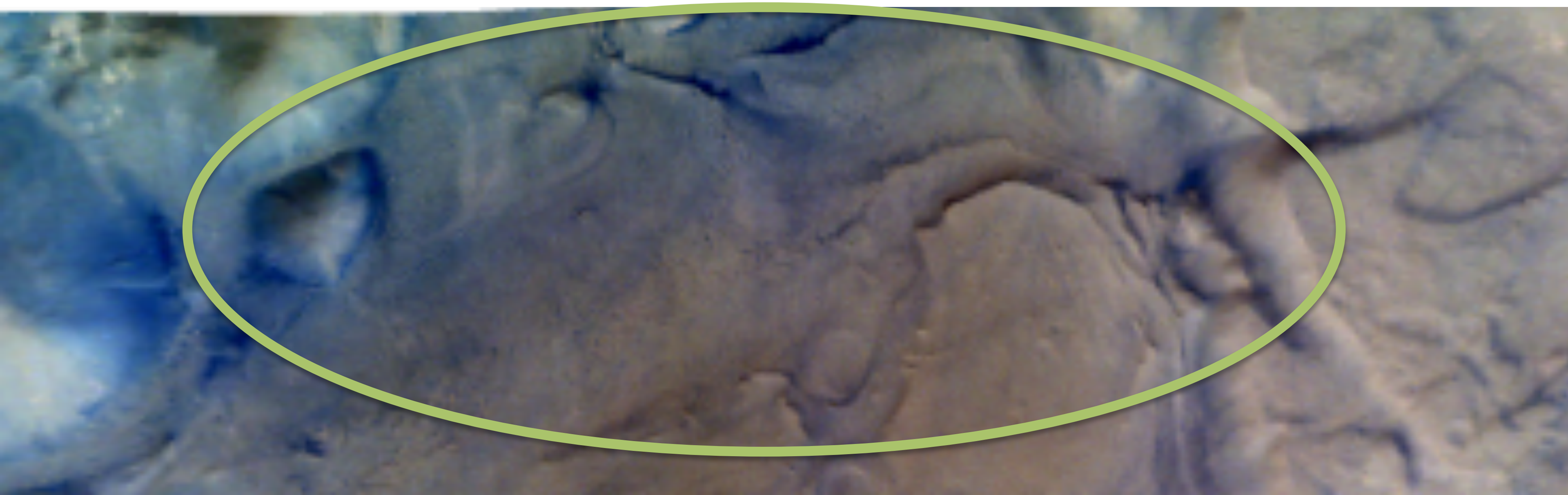


[in order of priority: addressing threshold first, then qualifying]

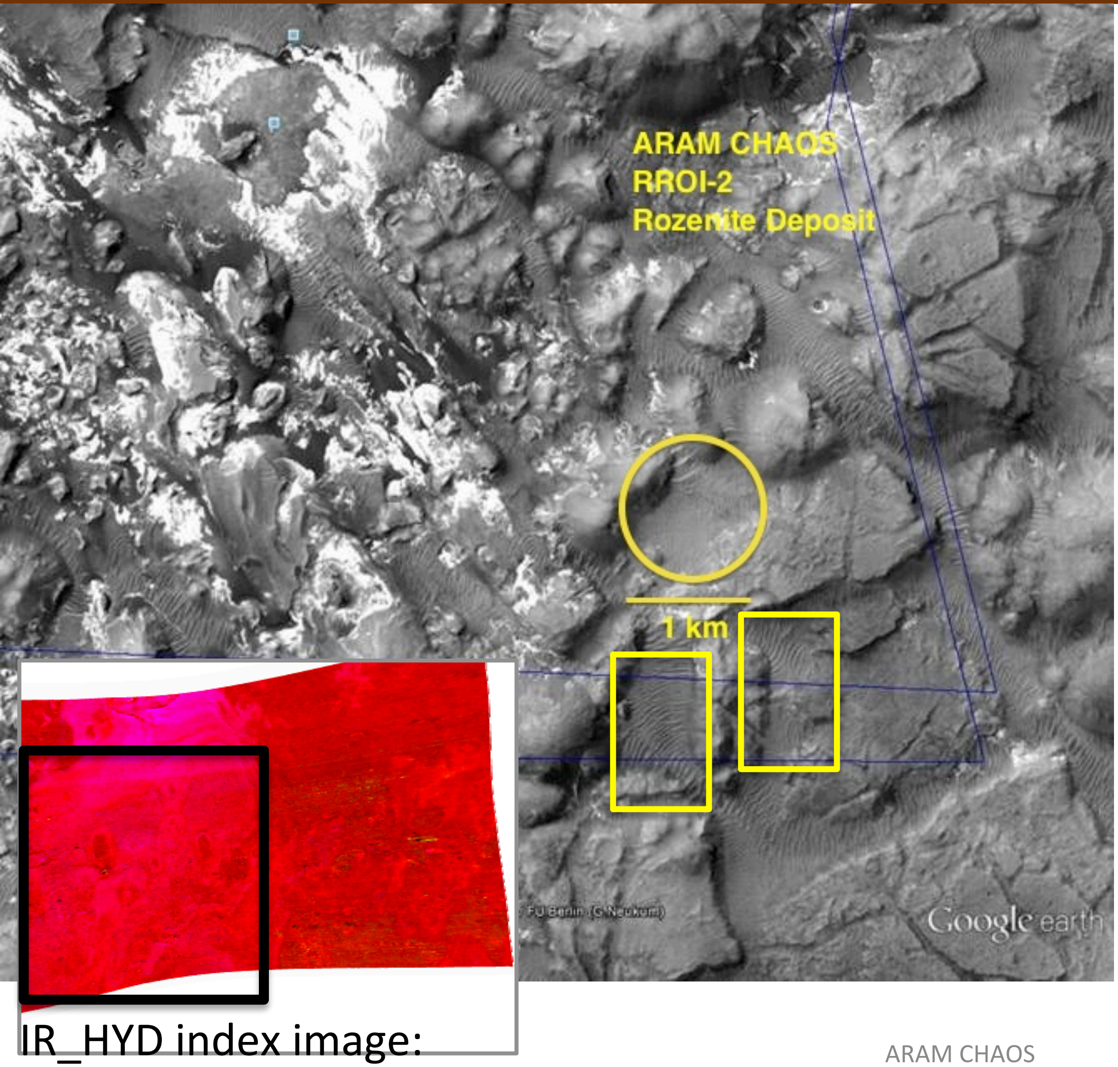
RESOURCE ROIs

Resource ROI 1: Poly-hydrated Sulfates

- 2º 26’ 40” N, 19º 44’ W, - 3.3 km
- Surface regolith contain poly-hydrated sulfates of est. water concentration 5-8 wt%
- Fine grained material suitable for surface strip mining ?
- Located ~ 500 meters (RROI-1) from LS
- Resource field is 2 km x 1 km; 1m deep assumed
- Potential water recovery ~ 172 t (87%) (equivalent to 11 MAV fuel cycles)
- Offers multiple mounds for radiation protection from Surface Power Units
- Slopes <2%, Good traverse paths and potential for sintered road paving



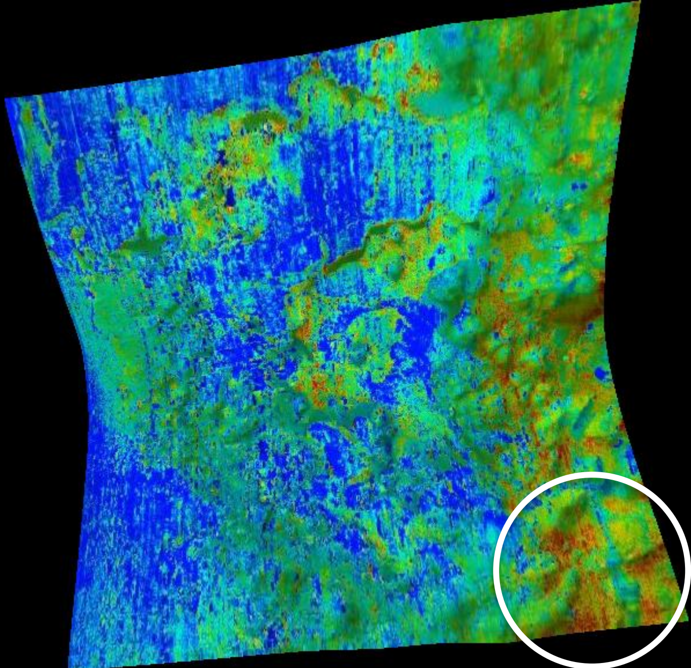
Resource ROI 2: Poly- and Mono-hydrated sulfates



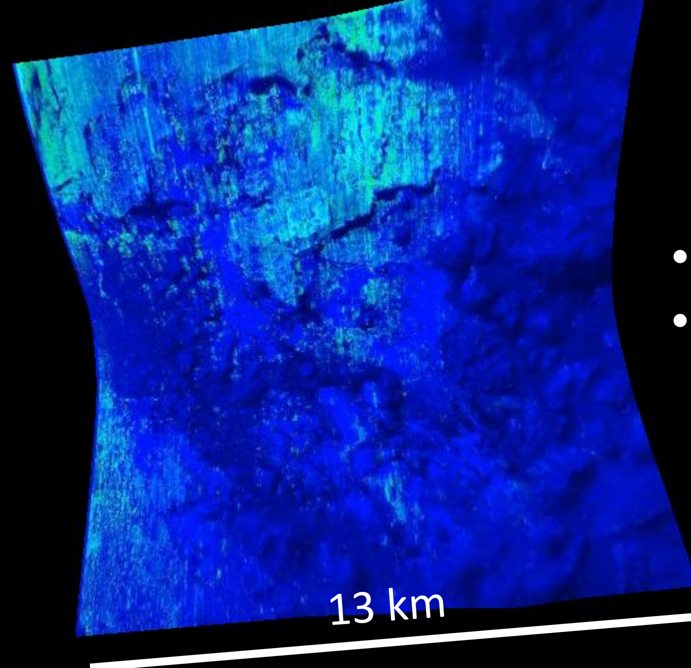
IR_HYD index image:
red indicates water containing minerals

- Mono-hydrated Sulfates
  - Kieserite ($MgSO_4 \cdot H_2O$)
- Poly-hydrated sulfates
  - Rozenite ($FeSO_4 \cdot 4H_2O$)
  - Epsomite ($MgSO_4 \cdot 7H_2O$)
- Representative case for PHS and MHS in area selected for abundance models
- 3.12°N 340.3°E
- ~ 40km from Landing site
- 4km x 1km fields
- Soft, friable material (?)
- Deposit water potential: 898.5 t (87% recovery yield), equivalent to 56 MAV fuel cycles)

RROI-2

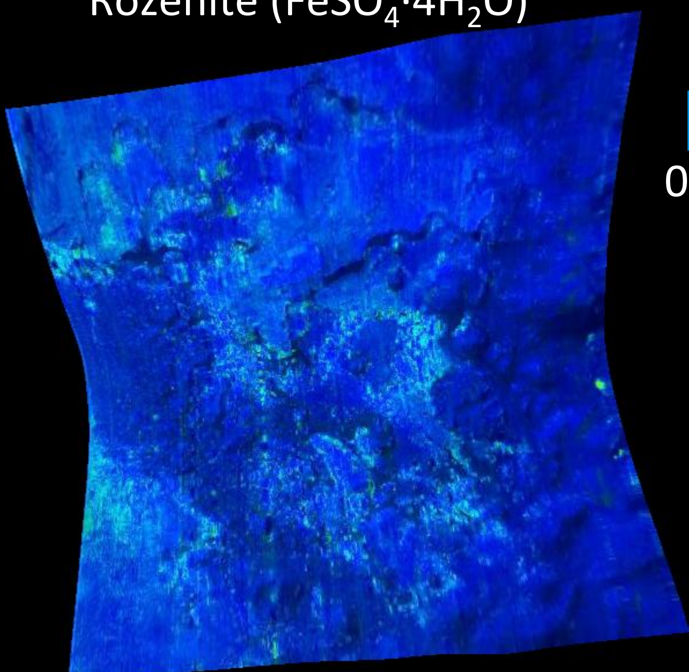


Rozenite ($FeSO_4 \cdot 4H_2O$)



Epsomite ($MgSO_4 \cdot 7H_2O$)

- CRISM FRT000164F0
- Quantitative unmixing of CRISM data converted to single scattering albedo using radiative transfer model (T. Glotch)



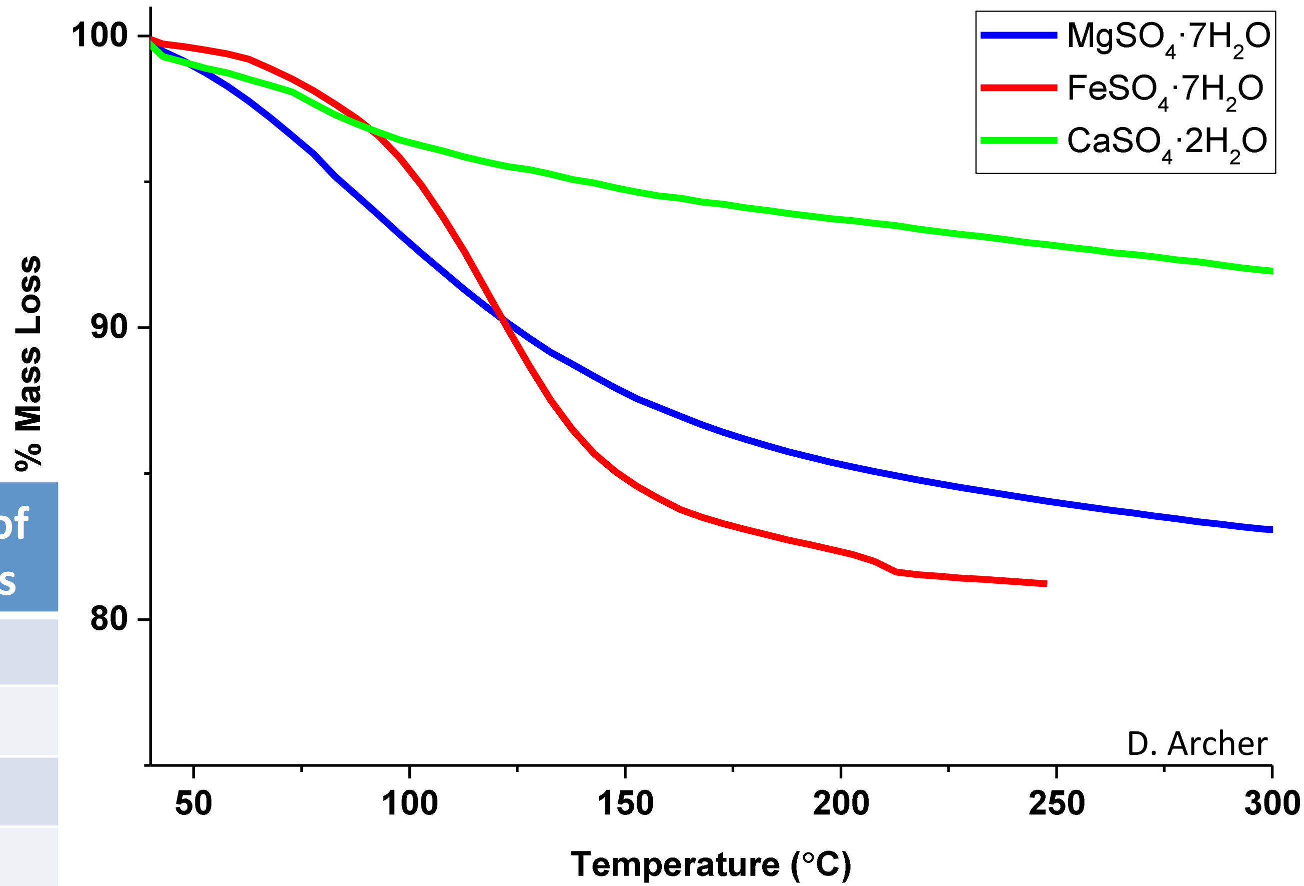
Kieserite ($MgSO_4 \cdot H_2O$)

- Major phases include dust, sulfate, oxides, and pyroxene
- Average PHS abundance in scene of 23% with max pixel value of 73%
- Average MHS abundance in scene of 5% with max pixel value of 53%

Water loss from poly-hydrated sulfates

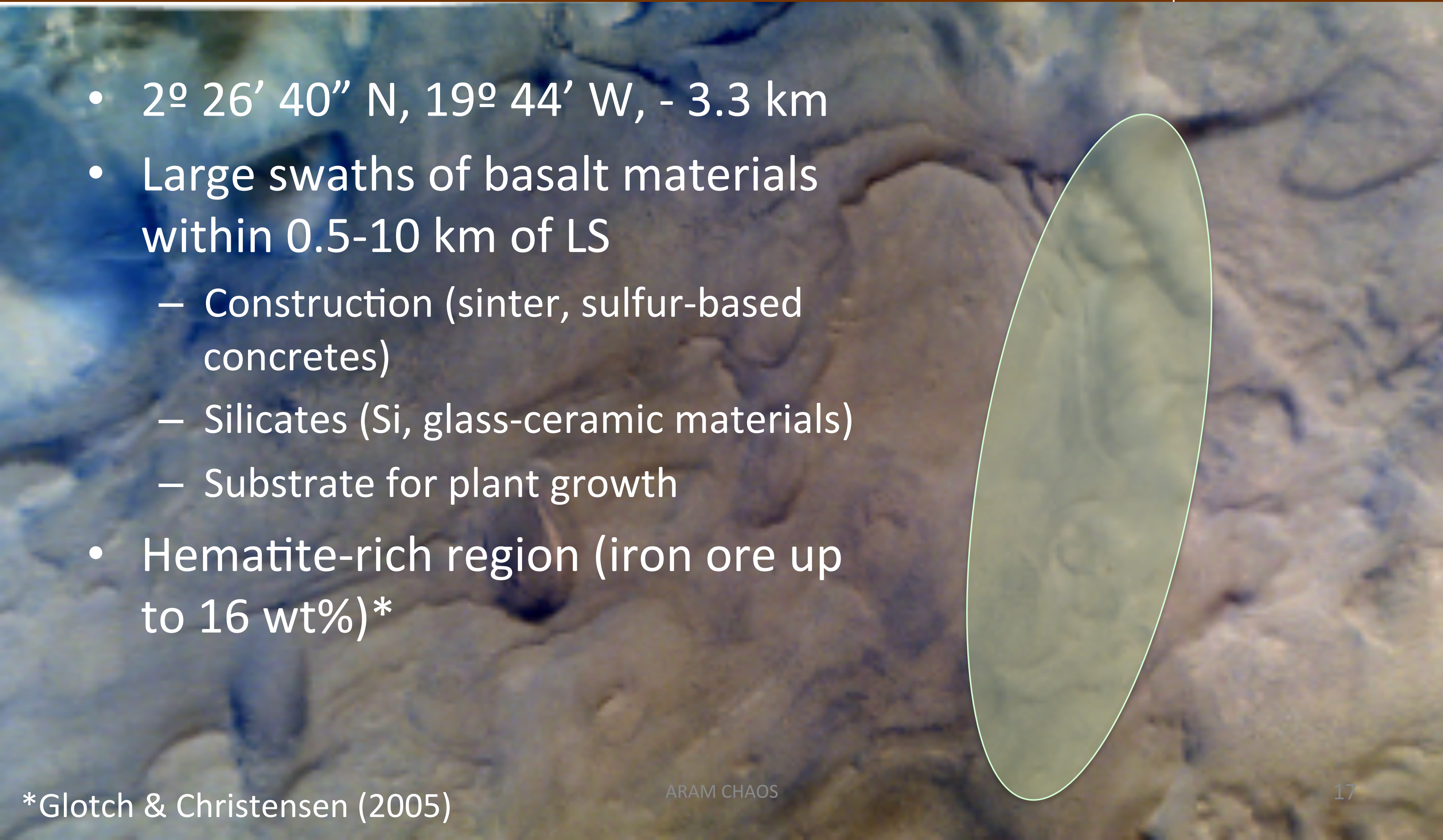
- Structural H_2O is generally released from sulfates by ~300 ºC.
- Structural OH can be released between ~400-800 ºC

Sulfate	H_2O as % of total mass
$MgSO_4 \cdot H_2O$	13
$MgSO_4 \cdot 7H_2O$	51
$FeSO_4 \cdot H_2O$	11
$FeSO_4 \cdot 7H_2O$	45
$CaSO_4 \cdot 0.5H_2O$	6
$CaSO_4 \cdot 2H_2O$	21



* TG water loss curves show water released after the samples were exposed to a dry He flow prior to analysis that removed some water

Resource ROI-3: Dark basalt regolith, hematite



- 2º 26’ 40” N, 19º 44’ W, - 3.3 km
- Large swaths of basalt materials within 0.5-10 km of LS
  - Construction (sinter, sulfur-based concretes)
  - Silicates (Si, glass-ceramic materials)
  - Substrate for plant growth
- Hematite-rich region (iron ore up to 16 wt%)*

*Glotch & Christensen (2005)

Case study of mining for water at Aram Chaos

UNSW AUSTRALIA
School of Mining Engineering

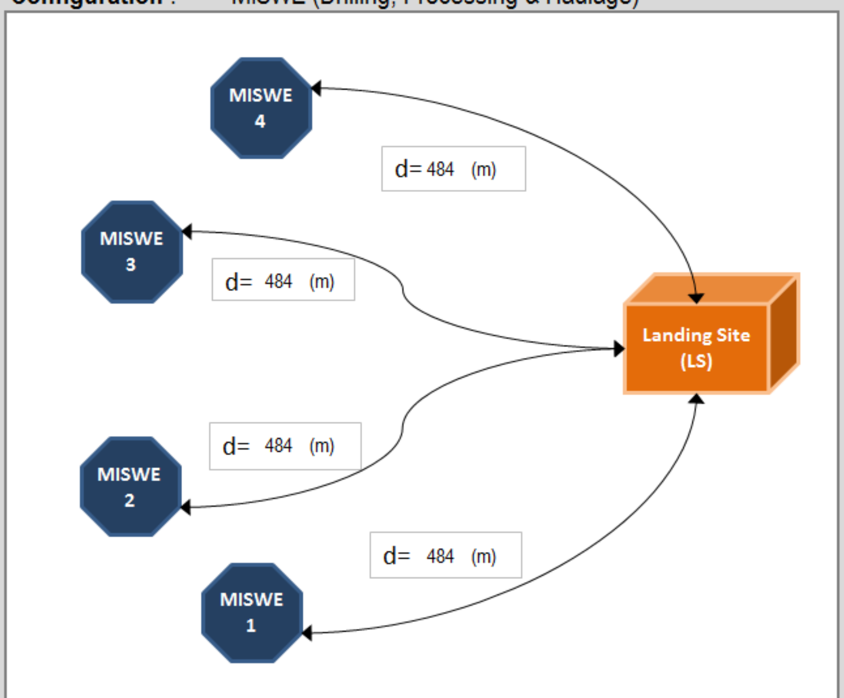
Water Extraction - Mars' Mining Model (WEM³)

KSC - Mars Landing site, distance to ROI assesment

Human Drinking Water Requirement:		3.66	(l/day)
		0.1525	(l/h)
Water Extraction Target:	Crew:	4	person
	H_2O:	0.61	(l/h)

Extraction Cycle		
Drilling	2.5	(h)
Processing	3.2	(h)
Haulage	6.7	(h)
Total Cycle	**12.5**	**(h)**
Equipment	**4**	**(unit)**
Production		
Per unit	0.15	(l/h)
Fleet	**0.61**	**(l/h)**

Configuration : MISWE (Drilling, Processing & Haulage)



MISWE: Mars In Situ Water Extractor (K. Zacny, Honeybee Robotics)

Linear programming optimisation technique
Technical (equipment) and geological constraints are main inputs.
Optimisation conducted to reach a target or to maximise performance.

***Target**: Provide enough water supply for a crew of four (4)*
***Optimization:** Distance between ROI and LS*

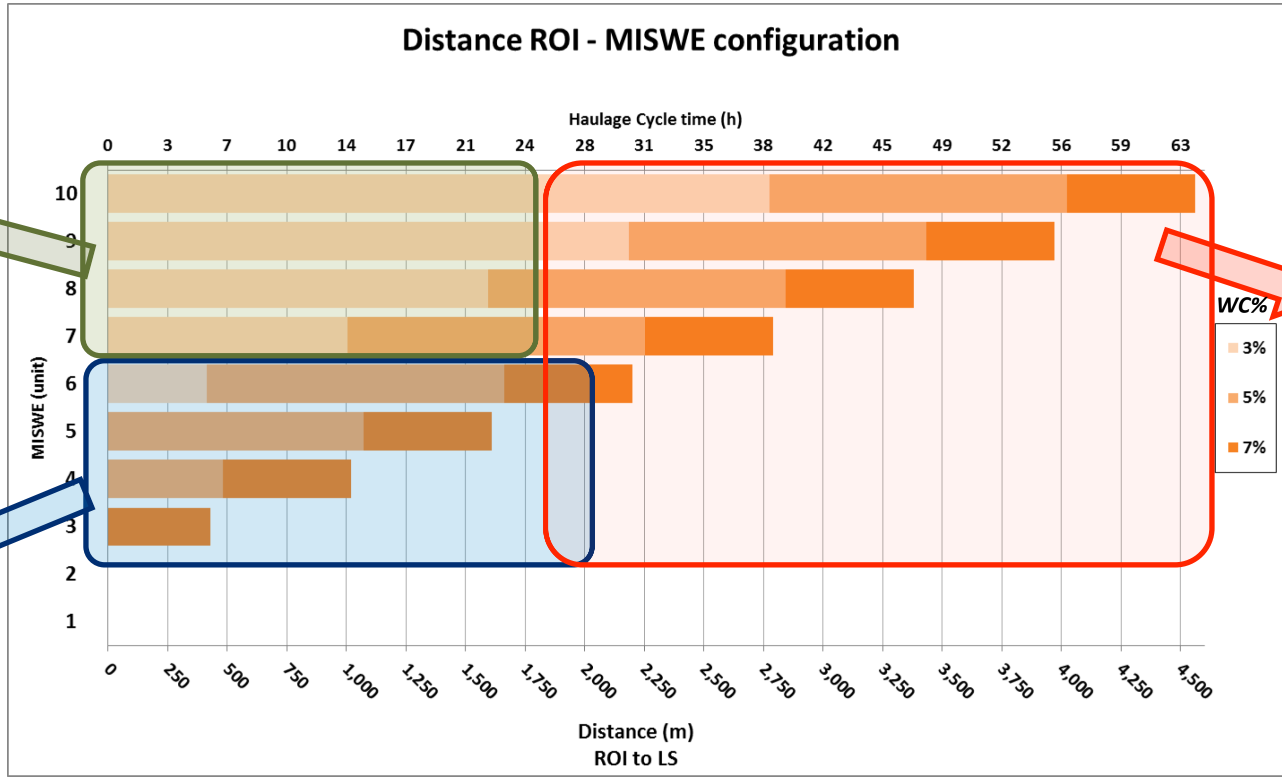
Water Contained in regolith (WC%): 3 wt.% to 7 wt.%
(5 wt.% as base case)
Based on human drinkable water requirement (3.66 L/day) for space missions.
Equipment:

- *Water recovery: 87%*
- *Water storage capacity 5 L*
- *Drilling rate: 1 m/h*
- *Speed: 2.4 m/min*

Case study of mining for water at Aram Chaos

Sensitivity results (WEM^3 model)

Intensive use of equipment. Heavy launching weight concerns



High risk during haulage activities.

The More Flexibility. Distance management to face WC% fluctuation

a. Water supply may not be assured by using less than 3 equipment.
b. WC% have the most significant impact on distance. If WC% decreases from 5% to 3% the allowed haulage distance drops by ~ 1.2 km. If it increases to 7% the allowed distance may rise about 0,5 km.
c. When distance increases time cycle also increases dramatically mainly due to long haulage cycle as a result of low equipment's speed.

Case study of mining for water at Aram Chaos

Conclusions and Recommendations

1. The use of 5 to 6 equipment in a distance no longer than 2.000 m seems to provide the most suitable configuration. It shows reasonable time cycles less than 24 hours and is also able to deal with unpredictable low WC% by reducing distance.

2. The configuration has the capacity to reach long distances; however, it may increase extraction risks due to the long cycle time and amount of resources required to face any eventual rescue mission if technical problems arise.

3. Mining system is most sensitive to WC%, thus geological information is required data.

4. Processing capacity and its performance are key to improving system's efficiency.

5. The system shows theoretical viability; however, the low processing performance, low speed and very selective drilling method may increases the risk of the mission in terms of continuous water supply. The evaluation of continuous mining at small scale is recommended.

6. A geological risk assessment that consider uncertainties about the "real" presence and distribution of water in regolith is highly recommended before design of any mining system. (surface or underground)

7. Further research in order to determine the optimum most suitable technology for the particular conditions of Aram Chaos (geology, topography and environment) is highly recommended to increase water supply certainty.

RUBRICS

Science ROI(s) Rubric

Site Factors					SROI1,2	SROI3	SROI4	SROI5	SROI6	RROI1	RROI2	RROI3	EZ SUM
Science Site Criteria	Astrobio	Threshold	AND/OR	**Potential for past habitability**	●	●	●	●	●	●	●	●	8,0
				Potential for present habitability/refugia	?	?	?	?	?	?	?	?	
		Qualifying		Potential for organic matter, w/ surface exposure	●	●	●	●	●	●	●	●	8,0
	Atmospheric Science	Threshold		**Noachian/Hesperian rocks w/ trapped atmospheric gases**	●	●	●	●	●	●	●	●	8,0
		Qualifying		Meteorological diversity in space and time	●	●	●	●	●	●	●	●	8,0
				High likelihood of surface-atmosphere exchange	●	●	●	●	●	●	●	●	8,0
				Amazonian subsurface or high-latitude ice or sediment									
				High likelihood of active trace gas sources	?	?	?	?	?	?	?	?	
	Geoscience	Threshold		**Range of martian geologic time; datable surfaces**	●	●	●	●	●	●	●	●	8,0
				Evidence of aqueous processes	●	●	●	●	●	●	●	●	8,0
				Potential for interpreting relative ages	●	●	●	●	●	●	●	●	8,0
		Qualifying		Igneous Rocks tied to 1+ provinces or different times									
				Near-surface ice, glacial or permafrost	?	?	?	?	?	?	?	?	
				Noachian or pre-Noachian bedrock units				●					1,0
				Outcrops with remnant magnetization									
				Primary, secondary, and basin-forming impact deposits				●					1,0
				Structural features with regional or global context	○	○	○	○	○	○	○	○	0,8
				Diversity of aeolian sediments and/or landforms	●	●	●	●	●	●	●	●	8,0

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars

Criteria	Resource	Type	Site Factors	SROI1,2	SROI3	SROI4	SROI5	SROI6	RROI1	RROI2	RROI3	EZ SUM
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)									
	Water Resource	**Threshold**	AND/OR **Potential for ice or ice/regolith mix**									0,0
			Potential for hydrated minerals	●	●	○	○	○	○	●	●	
			Quantity for substantial production	?	?	?	?	?	●	●	●	
			Potential to be minable by highly automated systems	○	○	○	○	○	●	●	●	
			Located less than 3 km from processing equipment site						●		●	
			Located no more than 3 meters below the surface	●	●				●	●	●	
			Accessible by automated systems	●	●				●	●	●	
		Qualifying	Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals									
			Distance to resource location can be >5 km							●		
			Route to resource location must be (plausibly) traversable						●		●	
	Civil Engineering	**Threshold**	**~50 sq km region of flat and stable terrain with sparse rock distribution**						?	?	?	
			1–10 km length scale: <10°						●	●	?	
			Located within 5 km of landing site location						●		●	
		Qualifying	Located in the northern hemisphere	●	●	●	●	●	●	●	●	
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	●	●	●	●	●	●	●	●	
			Utilitarian terrain features	●	●	●	●	●	●	●	●	
	Food Production	Qualifying	Low latitude	●	●	●	●	●	●	●	●	
			No local terrain feature(s) that could shadow light collection facilities	?	?	?	?	?	?	?	?	
			Access to water	●	●	○	○	○	●	●	●	
			Access to dark, minimally altered basaltic sands	●	●	●	●	●	●	●	●	
	Metal/Silicon Resource	**Threshold**	**Potential for metal/silicon**	●	●	○	○	○	●	●	●	○
			Potential to be minable by highly automated systems	●	●	○	○	○	●	●	●	
			Located less than 3 km from processing equipment site						●	?	●	
			Located no more than 3 meters below the surface	●	●				●	●	●	
			Accessible by automated systems	●	●				●	○	●	
		Qualifying	Potential for multiple sources of metals/silicon	●	●				?	?	?	
			Distance to resource location can be >5 km							●		
			Route to resource location must be (plausibly) traversable	●	●	●	●		●	?	●	

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Highest Priority EZ Data Needs

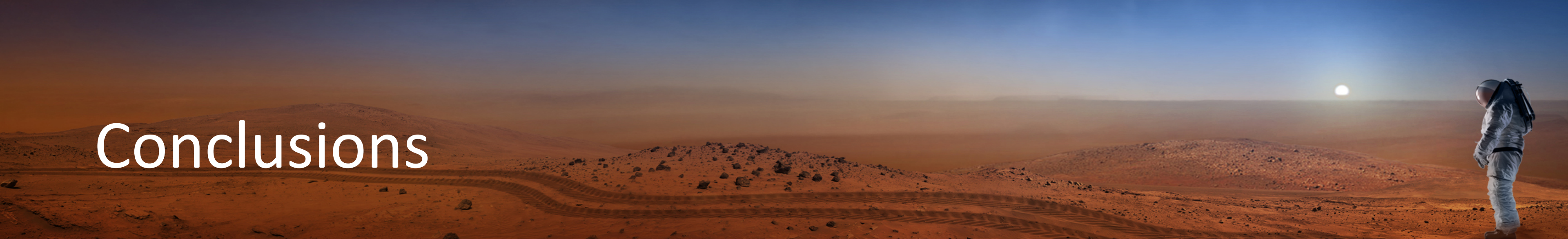
- **Resource/Science potential**
  - HIRISE stereo + CRISM: More complete coverage at high resolution to resolve topography, surface and subsurface deposits of water-rich minerals (top 10m)
  - Next generation radar: Depth information (top 10m and deeper) critical for mining and for subsurface geology must be obtained to inform possible buried layering and relict ice(?).
  - Surface scout rover to confirm water resources, initial science analyses

Prioritization List of EZ Data Needs

- Provide a prioritized list of orbiter/rover data to be collected to assess the science potential of the EZ.
- Provide a prioritized list of orbiter/rover data to be collected to assess the resource potential of the EZ.

- This data could be either from a current or future asset.
- If data to be collected are from existing assets please indicate:
  High spatial and spectral resolution in IR and temperature for Hyd minerals
  Hi-res of slope data
  - HiRISE
  - CRISM
  - THEMIS
  - Surface-based (precursor mission) or low altitude survey for mineral exploration: radar, sampling for size distributions, geotechnical properties, geological context

Provide a short justification as to what questions this will address.



Conclusions

- **ARAM CHAOS** can support long-term human presence and scientific exploration
- Landing sites at low elevation, low sloped areas
- **Science potential**
  - Chaos terrain indicates long lived subsurface water – protected habitable environment
  - Highly diverse geology, multiple aqueous episodes
  - Linked to other important geologic units across globe: Meridiani, Valles Marineris
- **Resource potential**
  - Confirmed PHS, MHS, hematite and basaltic dunes
  - Expected ability to provide primary and secondary resources to long-term field station
  - Surface roughness not well understood but very varied (fine-grained sulfates to collapsed blocks)
  - HIRISE, CRISM: More complete coverage at high resolution to discern surface and subsurface deposits of water-rich minerals (top 10m)
  - Further exploration from orbit and surface is needed to better understand geologic context for better resource characterization (mineral, water)
- **Landing site – Natural engineering solutions**
  - Chaotic arrangement of large mounds/blocks offer solutions for Habitat Zone:
    - Protection against lander ejecta, surface power radiation
    - Com and observation cameras placement
    - Partially built shelters
- **Need to bring mineral exploration expertise** on board (methodology, minimal techniques, map formations)


LS#2
THANK YOU
from Aram Chaos

BACKUP SLIDES

Aram Chaos